Development of Optical Metrology ENgine (OMEN)

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Background:

The Advanced Photon Source (APS) is a third-generation hard x-ray synchrotron radiation source located at Argonne National Laboratory, and funded by the US Department of Energy Office of Science-Basic Energy Sciences. It produces x-rays using synchrotron radiation from a 7 GeV storage ring. Plans are underway for an upgrade to improve the source brightness and coherent flux by orders of magnitude. New optics need be developed to preserve these improvements. It is the mission of the optics group to develop and analyze these optics.

Image courtesy of https://www1.aps.anl.gov/About/Welcome

Light Sources:

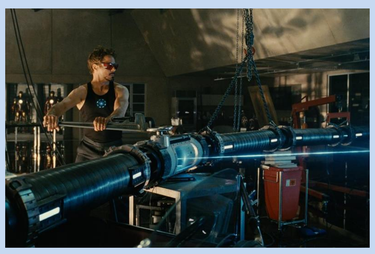
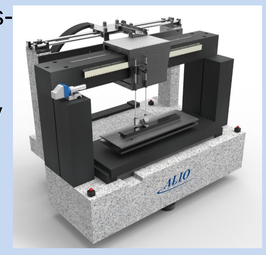


Image courtesy of http://www.animallogic.com/, *Iron Man 2*

- Electrons travel at relativistic speeds in a storage ring
  - At every bend, synchrotron radiation is released
- Light is extremely intense and highly collimated
- Extremely useful for a variety of experiments
  - Nanomaterial Investigation
  - Condensed matter physics
  - Protein Crystallography

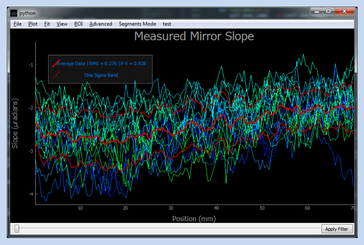
Mirrors:

- Upgrade requires residual slope error on mirrors as low as 50 nrad
  - Project focuses on analysis required to measure mirrors to the needed precision
- Optics group commissioned long trace profiler (LTP) to measure to the needed precision[1, 2]
  - Autocollimator-based slope measurement device
- LTP has very limited angular range
  - New procedure needed for highly curved mirrors
  - New analysis tools were needed

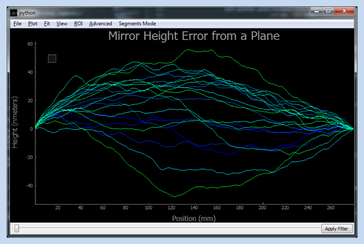


OMEN Capabilities:

Data Visualization



Filtering potential high-background scans

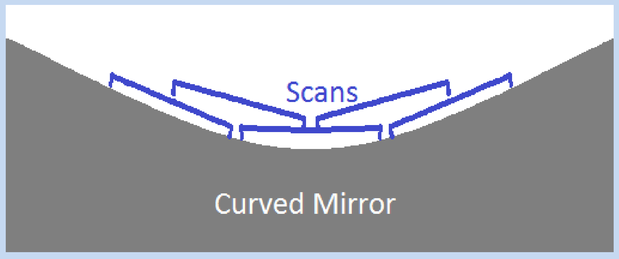


Region of Interest Selection

Fitting with easy analysis of the fit residue

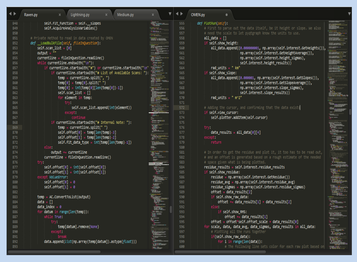
New Procedures for Curved Mirrors

- Make and apply calibration curves to extend LTP range
- Stitching partial scans together so each reads only the accurate regime of the LTP



OMEN Technical Details:

- Python software
  - PyQt4 based GUI
  - PyQtGraph based plotting
- Class-based architecture:



OMEN handles the GUI and companion classes

Raven does data collection and analysis

Image courtesy of Blazon.com/heraldry/

Lightning stitches partial scans together

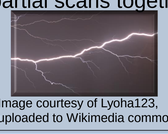


Image courtesy of Lyoha123, uploaded to Wikimedia commons

Medium converts backend data to standard forms

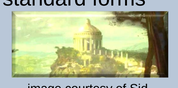
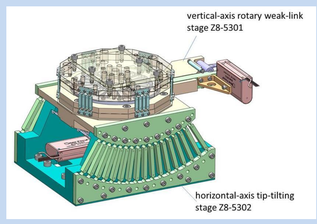


image courtesy of Sid Meier's Civilization V

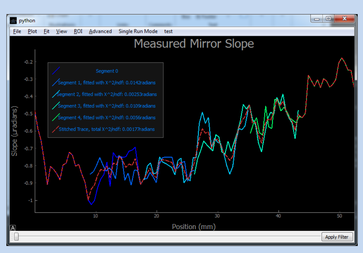
Data Collection:



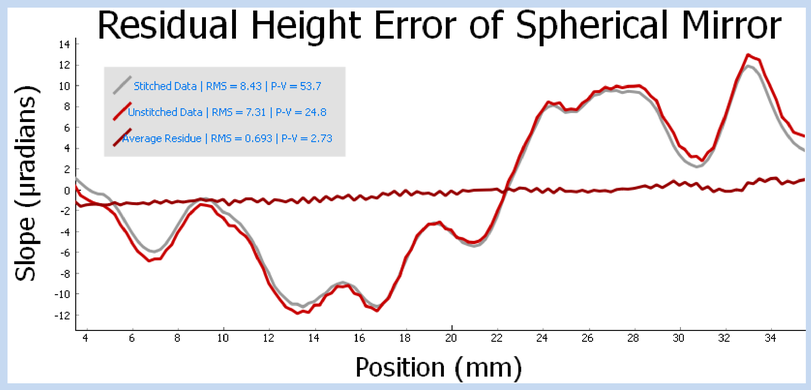
- New, high precision stage[3]
  - Mirror movement precise on the order of 10 nrad
- Stitched measurement compared to single-run full measurement for flat, elliptical, and spherical mirrors

Results:

Test stitching partial scans by comparing to a full scan



- RMS of difference is an order of magnitude smaller than the residual RMS of either mirror
  - Indicates the process is effective
- Deviation between stitched and unstitched is linear on a spherical mirror
  - Comparison with calibrated data will be performed



Conclusions:

- Code is robust, and will be useful for future analysis
  - Easy to use
  - Rapid analysis
- Stitching code allows for new measurement capability
- Further investigation will be conducted into calibration in the near future

References:

1. Lahsen Assoufid et al., Nucl. Instrum. Methods A 710, 31-36 (2013).
2. J. Qian, J. Sullivan, M. Erdmann, A. Khounsary, L. Assoufid, Nucl. Instrum. Methods A 710, 48-51 (2013).
3. D. Shu, et al., Proc. SPIE 9206, Advances in Metrology for X-Ray and EUV Optics V, 920601 (October 7, 2014); doi: 10.1117/12.2084726Proc. of SPIE Vol. 9206,

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